CHAPTER 2

JOINTED CONCRETE (JC) PAVEMENT DESIGN

2-1. Uses. JC pavement, meeting the requirements contained herein, can be used for any pavement facility. The only restriction to the use of JC pavement pertains to unusual conditions that may require minimal reinforcement of the pavement as outlined in chapter 3.

2-2. Thickness design curves. Figures 2-1 through 2-3 are design curves for design Classes I, II, and III defined in table 1-1. Figure 2-4 is a design curve for shoulder pavements applicable to all design classes. (Curves for Air Force light, medium, heavy loads, and short field, figures 2-5 through 2-8, are included for reference.)

a. JC pavements on nonstabilized or modified soil foundations. For JC pavements that will be placed directly on nonstabilized or modified base courses or subgrade, the thickness requirement h_{dc} will be determined from the appropriate design curve using the design parameters of concrete flexural strength R, modulus of soil reaction k, gross weight of aircraft, aircraft pass level, and pavement traffic area type (except the shoulder design). When the thickness from the design curve indicates a fractional value, it will be rounded to the nearest full-or half-inch thickness. Values falling exactly on 0.25 or 0.75 inch will be rounded upward. Pavement thickness may be modified within narrow limits by the use of higher flexural strengths, stabilized layers (b below) to increase the foundation supporting value, or by the addition of reinforcing steel. When it is necessary to change from one thickness to another within a pavement facility, such as from one type traffic area to another, the transition will be accomplished in one full paving lane width or slab length.

b. JC pavements on stabilized base and/or subbase. Stabilized base and/or subgrade layers meeting the strength requirements of paragraph 1-8a and Econocrete will be treated as low-strength base pavements, and the JC pavement thickness will be determined using the following modified, partially bonded rigid overlay pavement design equation:

$$h_{doc} = \sqrt[1.4]{h_{dc}^{1.4} - \left(0.0063\sqrt[3]{E_{fc}}\, h_b\right)^{1.4}}$$

The required thickness determined by this equation will be rounded to the nearest full- or half-inch thickness for construction. Values falling midway between the half and full inch will be rounded upward.

2-3. Jointing. Joints are provided to permit contraction and expansion of the concrete resulting from temperature and moisture changes, to relieve warping and curling stresses due to temperature and moisture differentials, to prevent unsightly irregular breaking of the pavement, and as a construction expedient to separate sections or

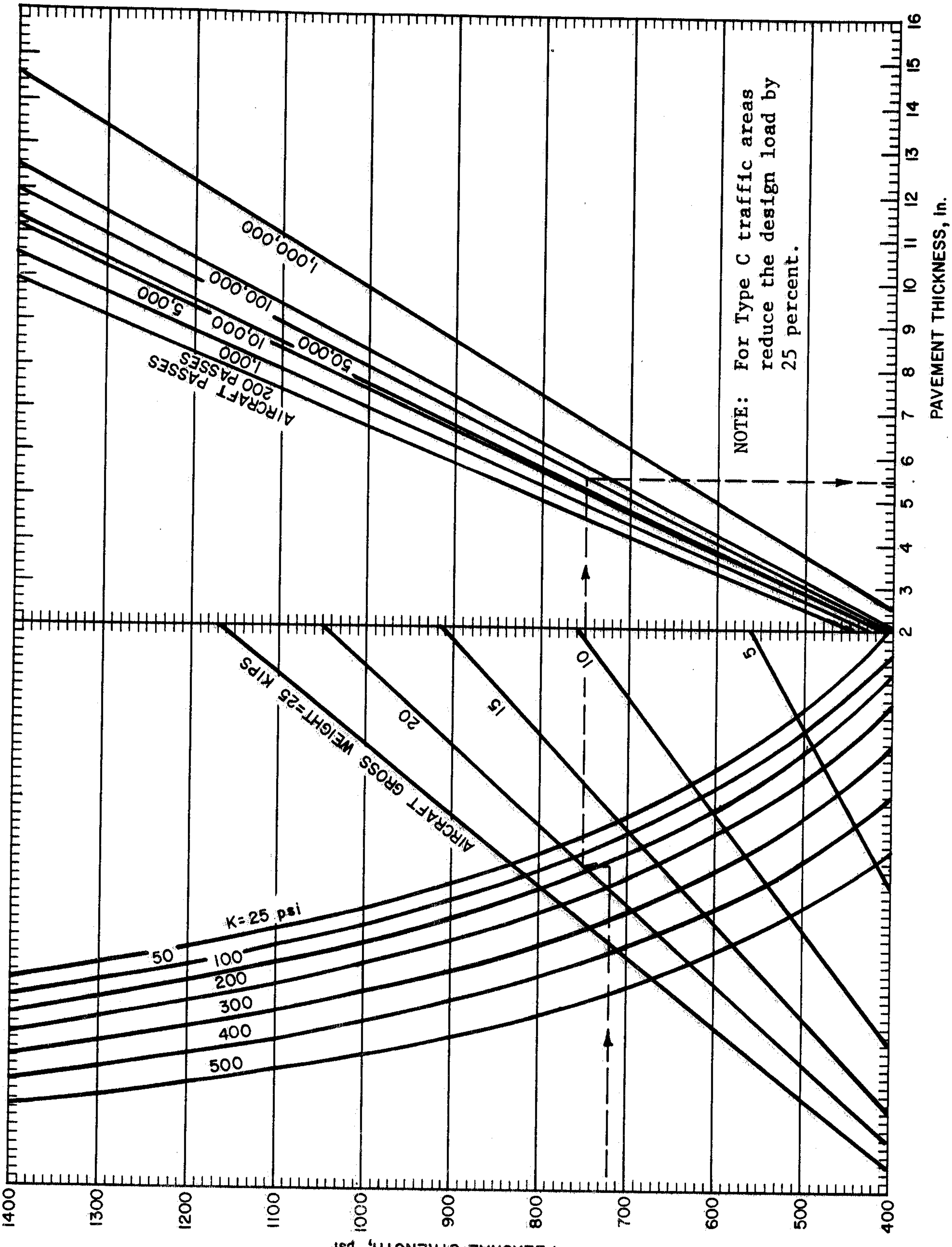

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FIGURE 2-1. JC PAVEMENT DESIGN CURVES FOR ARMY CLASS I PAVEMENTS

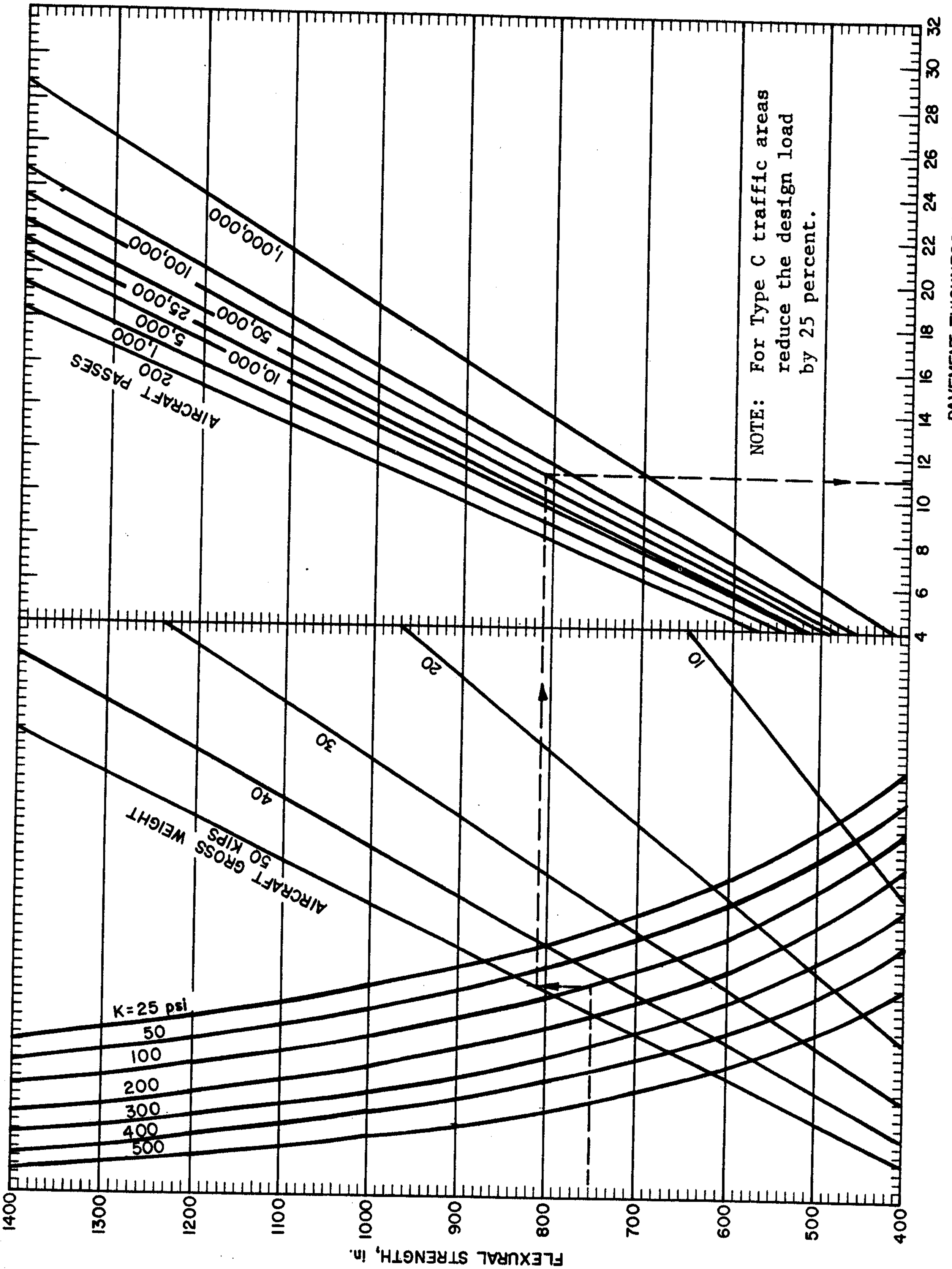

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FIGURE 2-2. JC PAVEMENT DESIGN CURVES FOR ARMY CLASS II PAVEMENTS

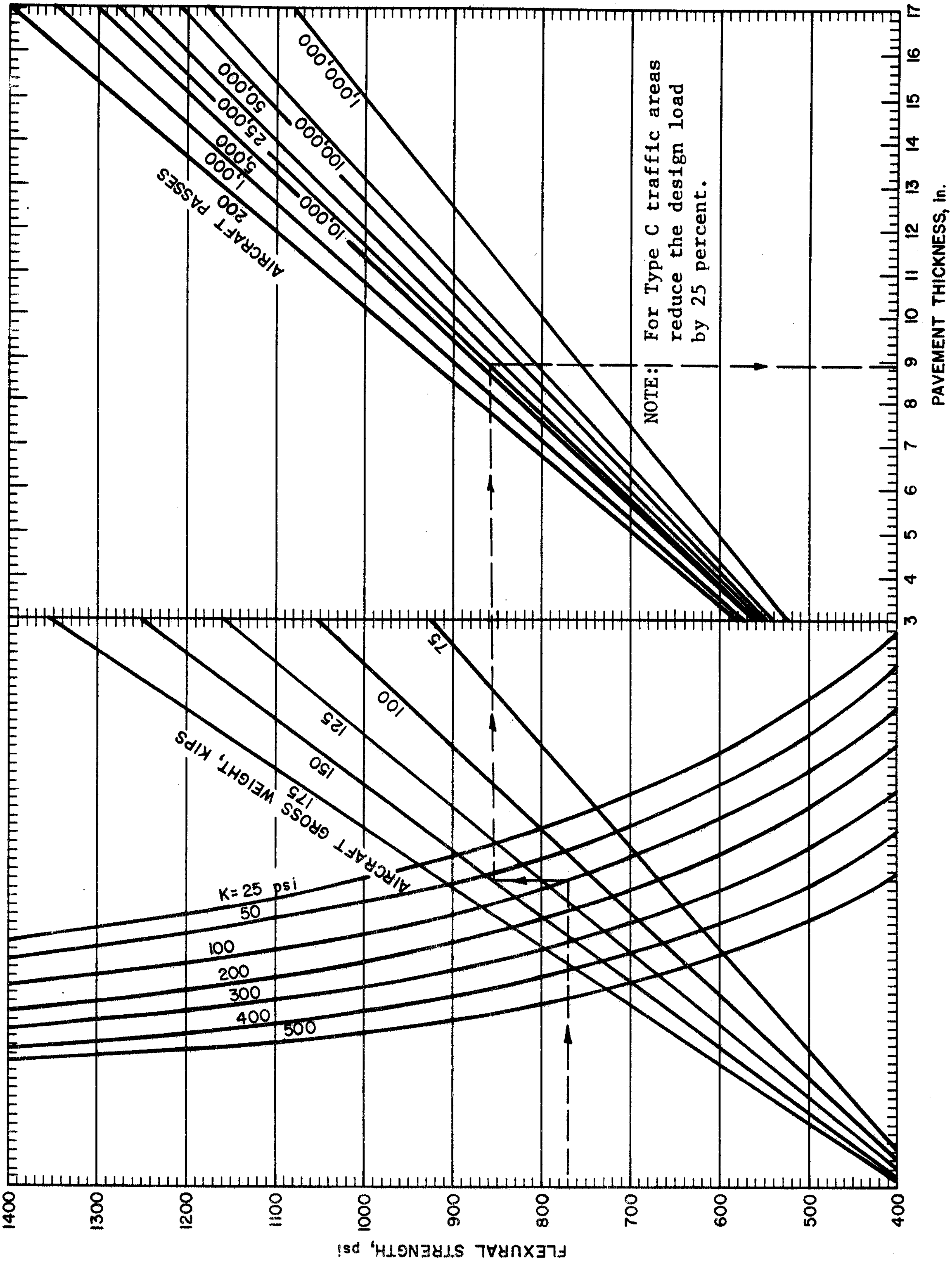

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FIGURE 2-3. JC PAVEMENT DESIGN CURVES FOR ARMY CLASS III PAVEMENTS

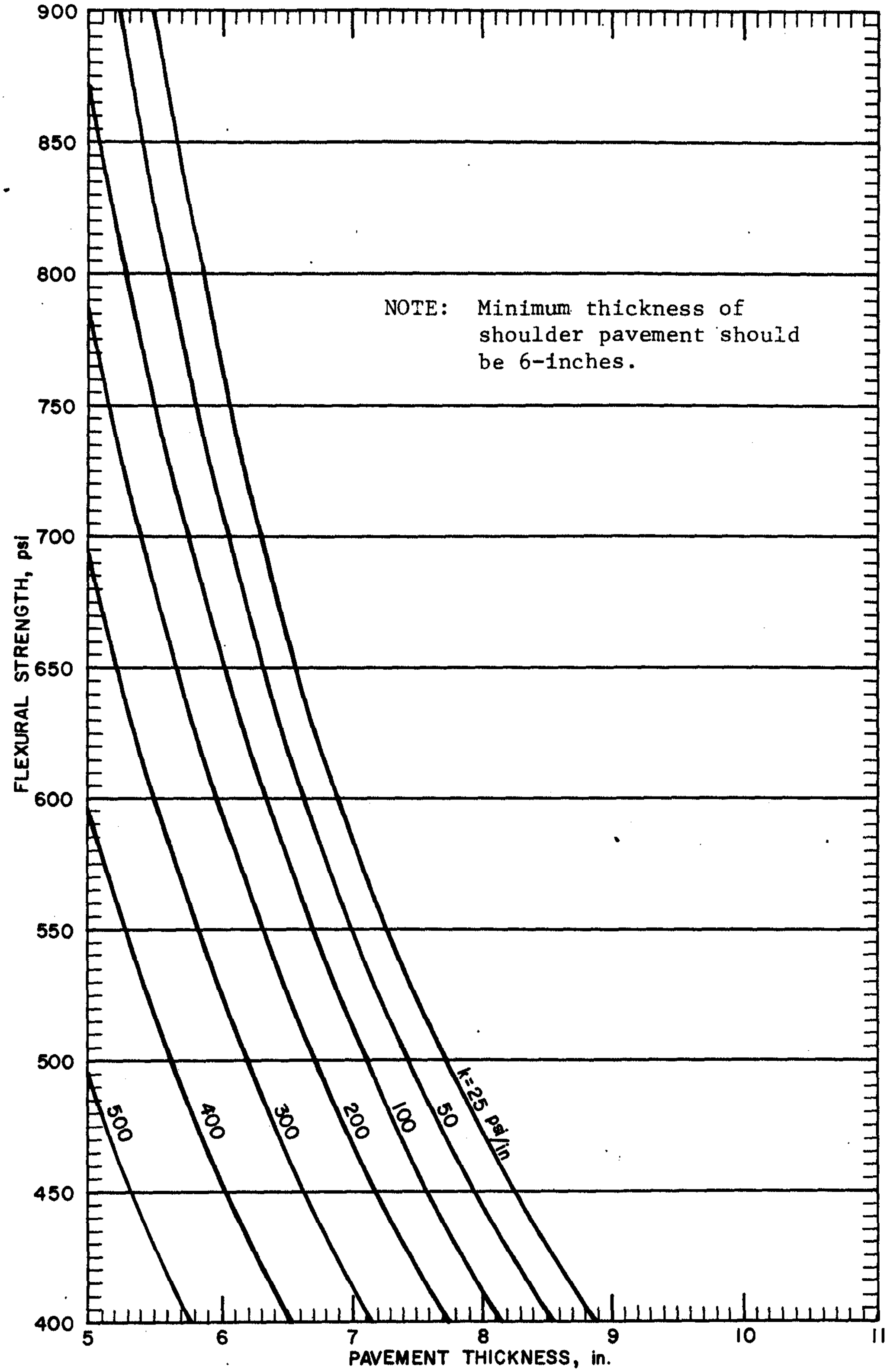

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FIGURE 2-4. PAVEMENT DESIGN CURVES FOR SHOULDERS

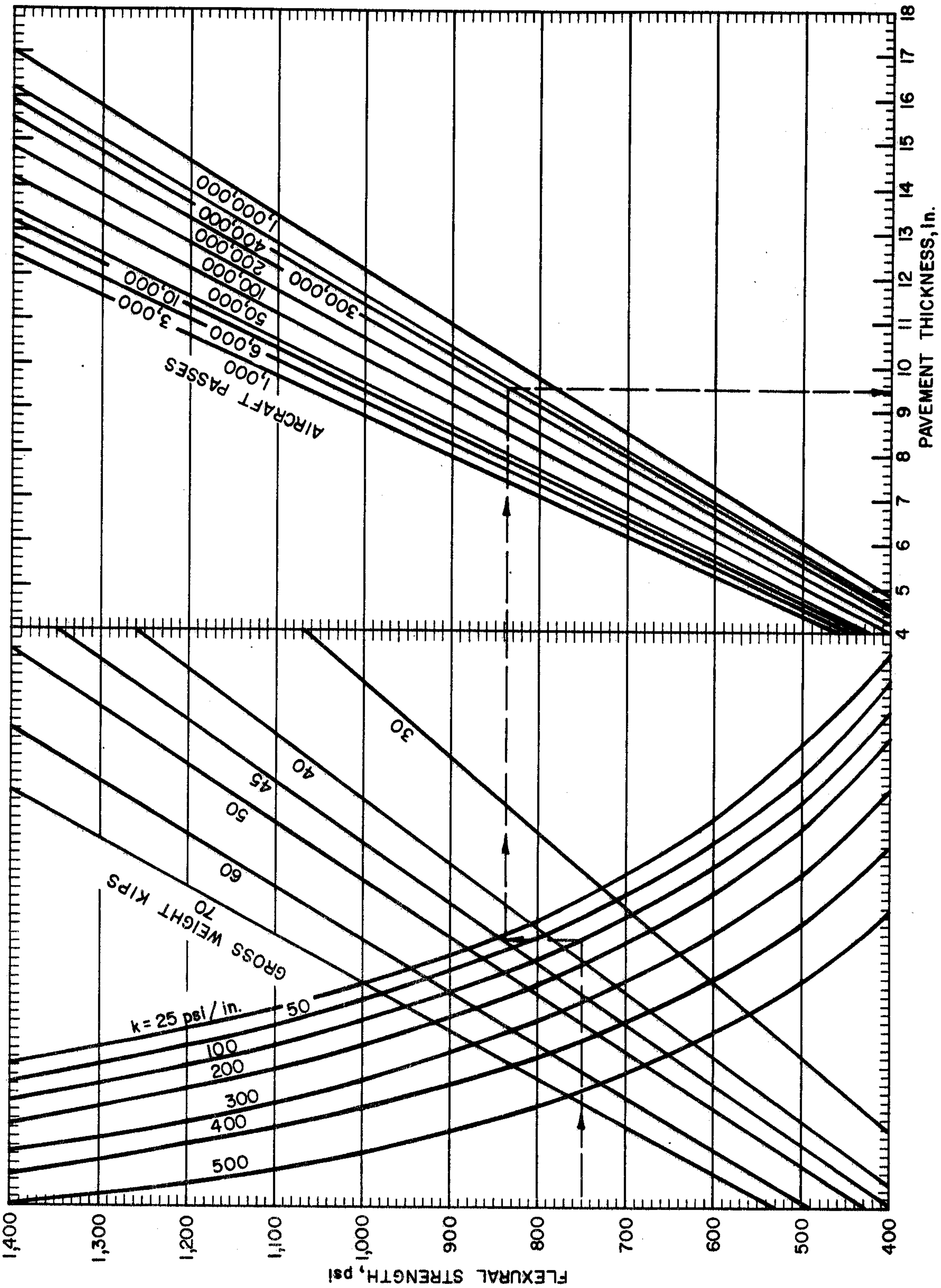

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FIGURE 2-5. JC PAVEMENT DESIGN CURVES FOR AIR FORCE LIGHT-LOAD PAVEMENTS

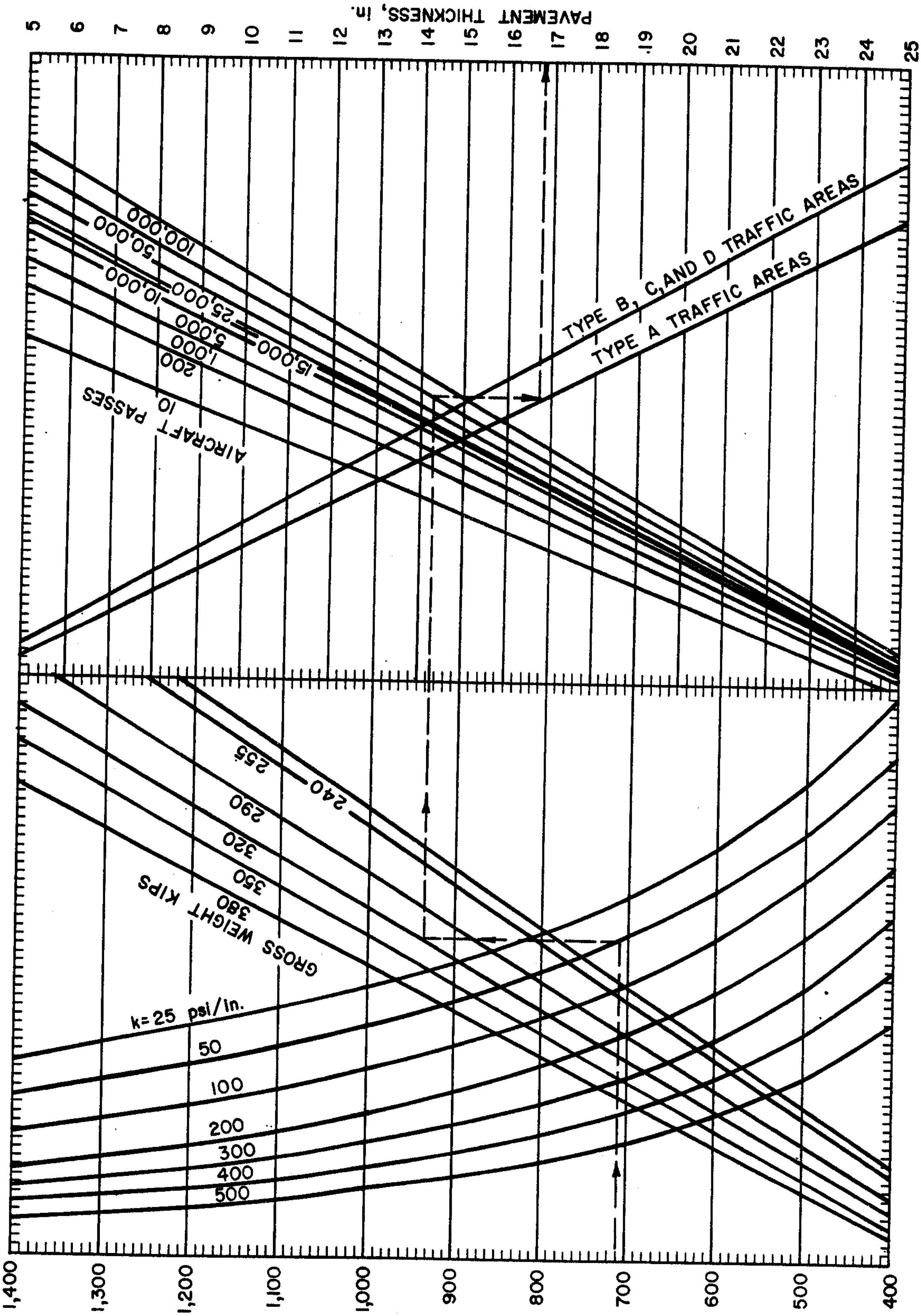

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FIGURE 2-6. JC PAVEMENT DESIGN CURVES FOR AIR FORCE MEDIUM-LOAD PAVEMENTS

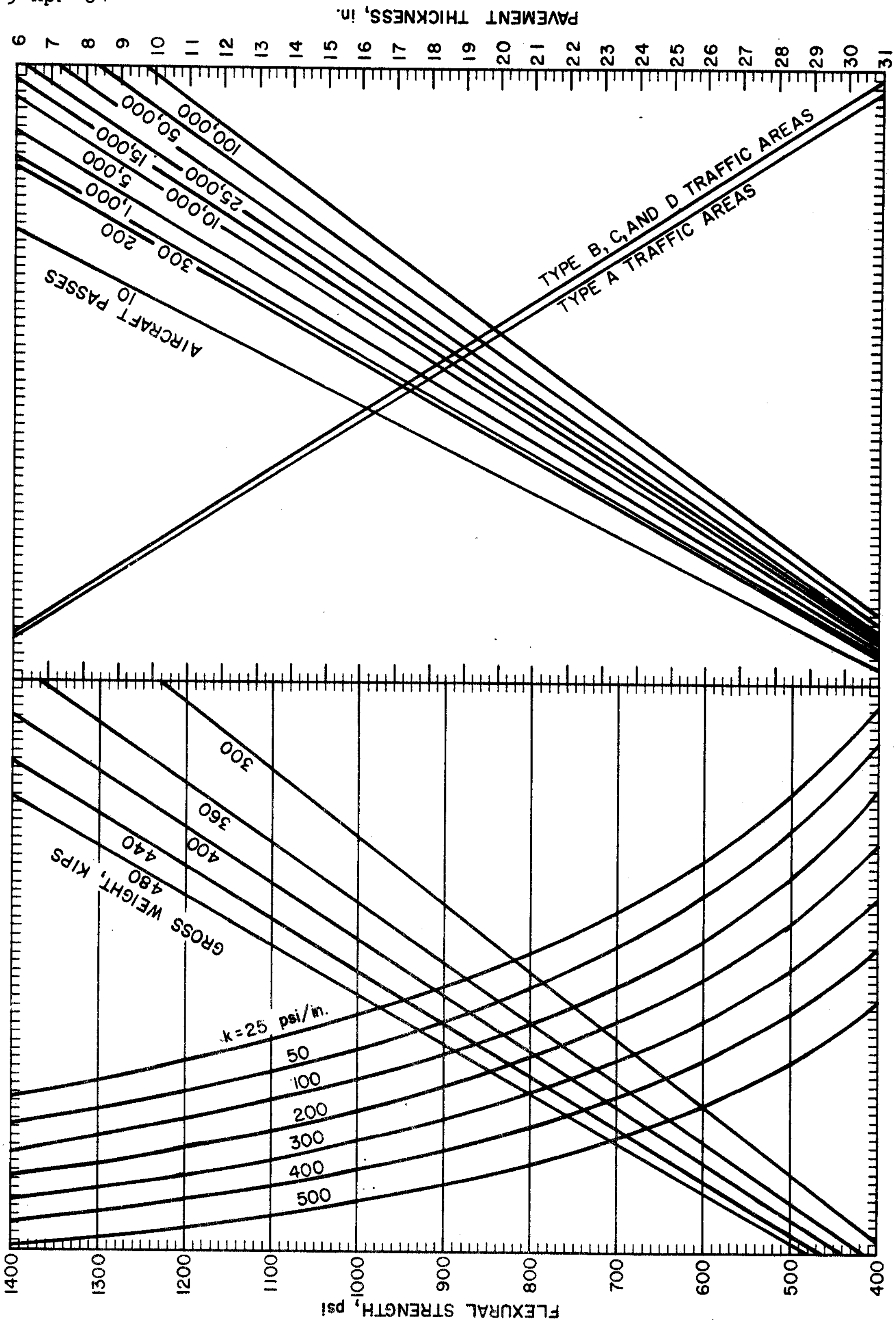

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FIGURE 2-7. JC PAVEMENT DESIGN CURVES FOR AIR FORCE HEAVY-LOAD PAVEMENTS

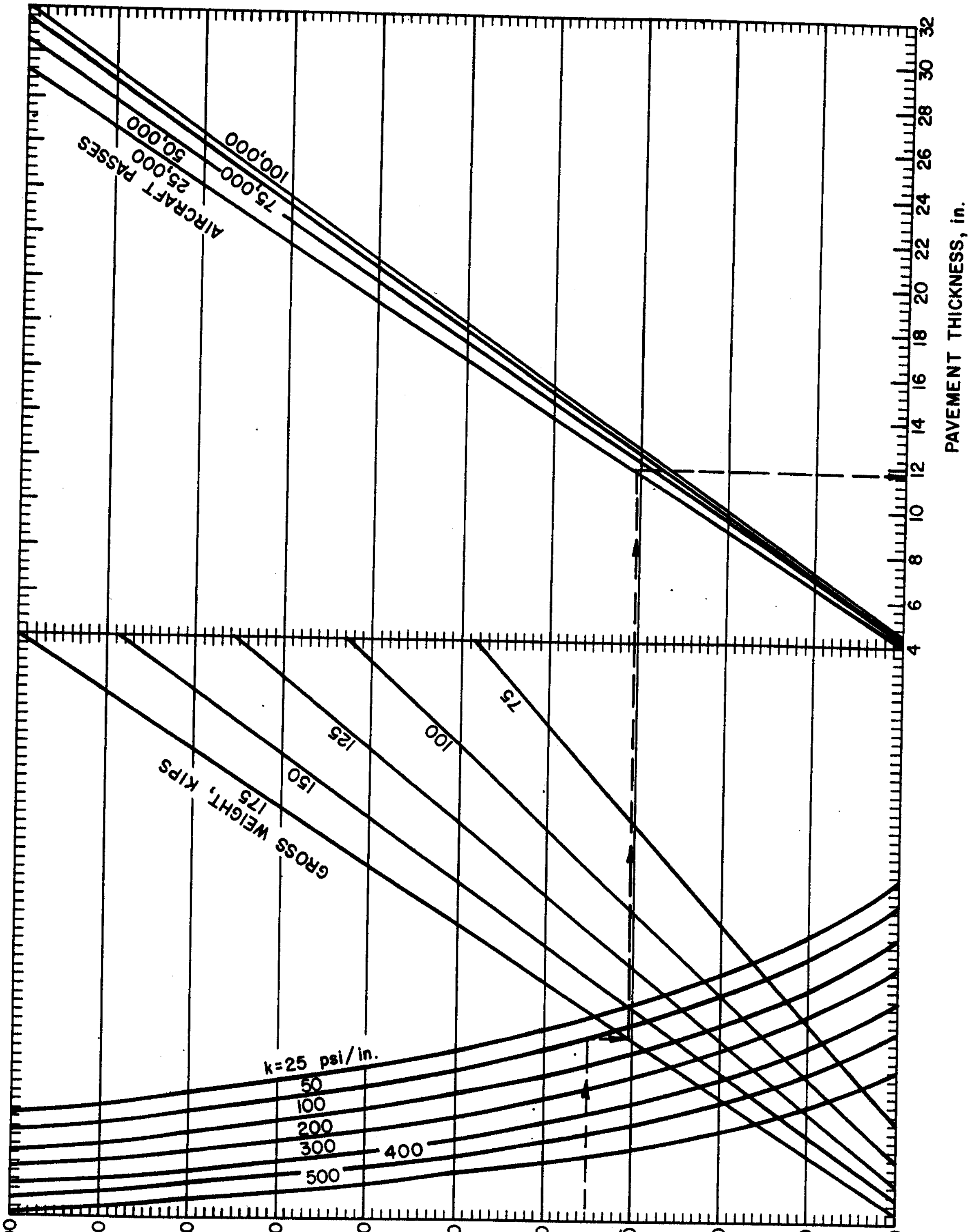

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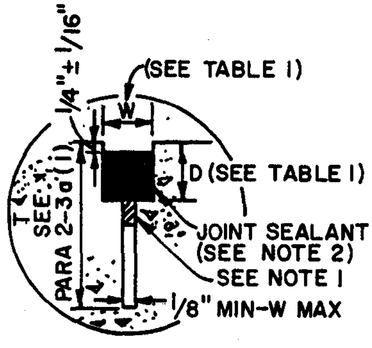
FIGURE 2-8. JC PAVEMENT DESIGN CURVES FOR AIR FORCE SHORT FIELD PAVEMENTS strips of concrete placed at different times. The three general types of joints, contraction, construction, and expansion, are shown in figures 2-9, 2-10, and 2-11, respectively. A typical jointing of the three types is illustrated in figure 2-12.

a. Contraction joints. Weakened-plane contraction joints are provided to control cracking in the concrete and to limit curling or warping stresses resulting from drying shrinkage and contraction and from temperature and moisture gradients in the pavement, respectively. Shrinkage and contraction of the concrete causes slight cracking and separation of the pavement at the weakened planes, which will provide some relief from tensile forces resulting from foundation restraint and compressive forces caused by subsequent expansion. Contraction joints will be required transversely and may be required longitudinally depending upon pavement thickness and spacing of construction joints.

(1) Width and depth of weakened plane groove. The width of the weakened plane groove will be a minimum of 1/8 inch and a maximum equal to the width of the sealant reservoir contained in paragraph (2) below. The depth of the weakened plane groove must be great enough to cause the concrete to crack under the tensile stresses resulting from the shrinkage and contraction of the concrete as it cures. This depth should be at least one fourth of the slab thickness for pavements 12 inches or less, 3 inches for pavements greater than 12 and less than 18 inches in thickness, and one sixth of the slab thickness for pavements greater than 18 inches in thickness. In no case will the depth of the groove be less than the maximum nominal size of aggregate used.

(2) Width and depth of sealant reservoir. The width and depth of the sealant reservoir for the weakened plane groove will conform to dimensions shown in figure 2-9. The dimensions of the sealant reservoir are critical to satisfactory performance of the joint sealing materials.

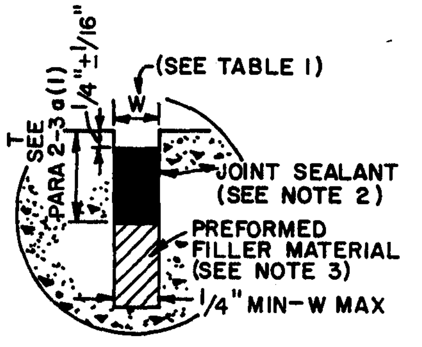
(3) Spacing of transverse contraction joints. Transverse contraction joints will be constructed across each paving lane, perpendicular to the center line, at intervals of not less than 12-1/2 feet and generally not more than 25 feet. The joint spacing will be uniform throughout any major paved area, and each joint will be straight and continuous from edge to edge of the paving lane and across all paving lanes for the full width of the paved area. Staggering of joints in adjacent paving lanes can lead to sympathetic cracking and will not be permitted unless reinforcement, as described in paragraph 3-2b, is used. The maximum spacing of transverse joints that will effectively control cracking will vary appreciably depending on pavement thickness, thermal coefficient and other characteristics of the aggregate and concrete, climatic conditions, and foundation restraint. It is impracticable to establish limits on joint spacing that are suitable for all conditions without making them unduly restrictive. The joint spacings in table 2-1 have given satisfactory



SAWED

TABLE I

CONTRACTION JOINT SPACING, ft.	DIMENSIONS, in.	
	W	D
<20	3/8 ± 1/16	3/4 ± 1/16
20–25	1/2 ± 1/16	1 ± 1/16
>25–50	3/4 ± 1/16	1-1/4 ± 1/16
>50–100	1 ± 1/16	1-1/2 ± 1/16



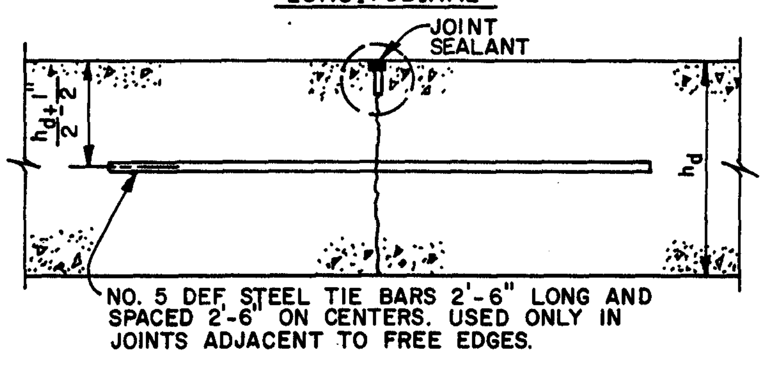
PREFORMED

NOTE 1: Nonabsorptive material required to prevent joint sealant from flowing into sawcut and to seperate noncompatible materials.

2: Joint sealant may be pourable or preformed type (see para 2-3e).

3: Preformed filler may be fiberboard or other approved material which can be sawed or which can have a section removed to form a sealant reservoir.

LONGITUDINAL



TRANSVERSE

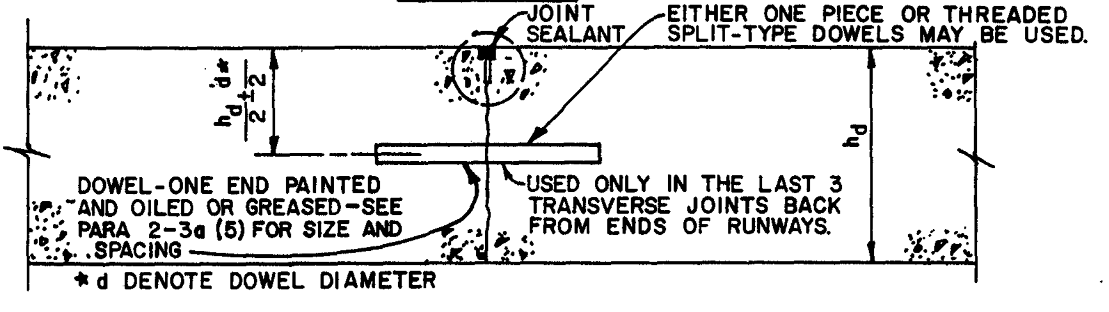


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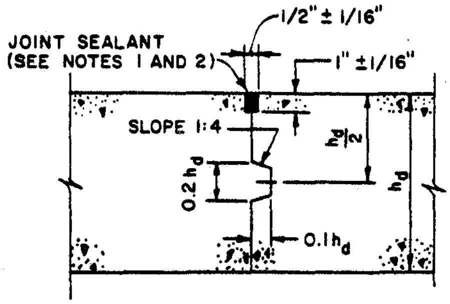
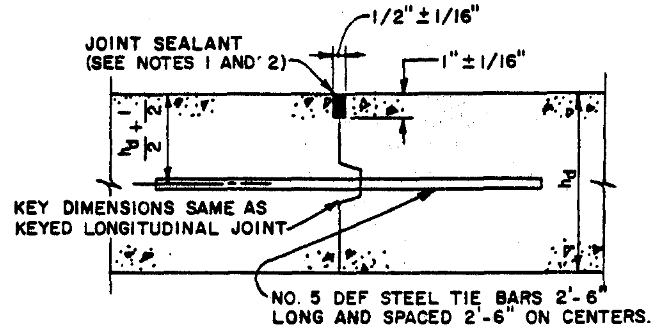
FIGURE 2-9. CONTRACTION JOINTS FOR JC PAVEMENTS

KEYED LONGITUDINAL

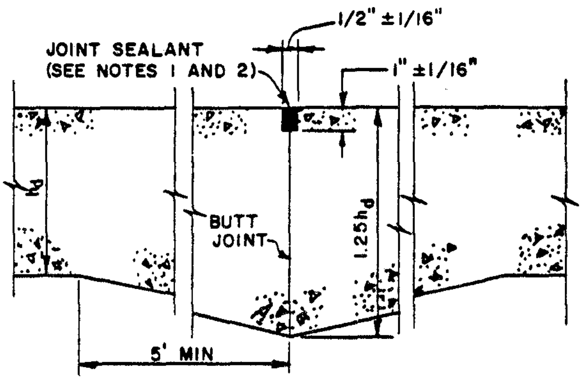


NOTE: A tolerance of plus of minus 1/16 inch may be allowed for key dimensions and location.

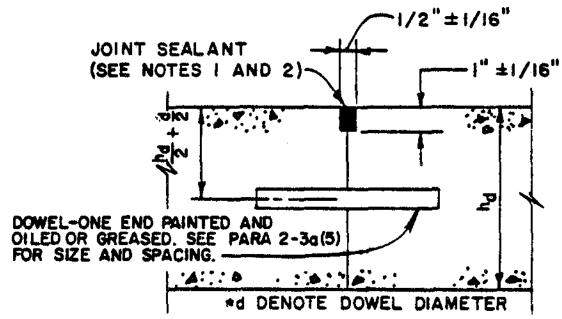
KEYED AND TIED LONGITUDINAL



THICKENED EDGE LONGITUDINAL

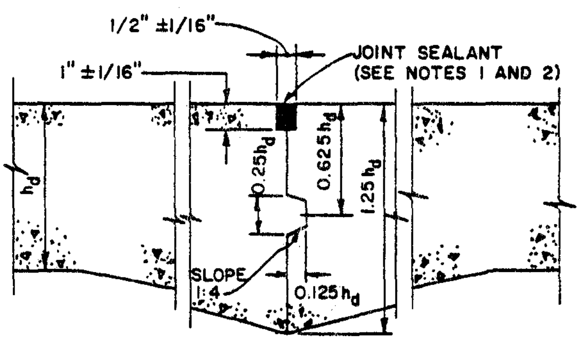


DOWELED TRANSVERSE
OR LONGITUDINAL

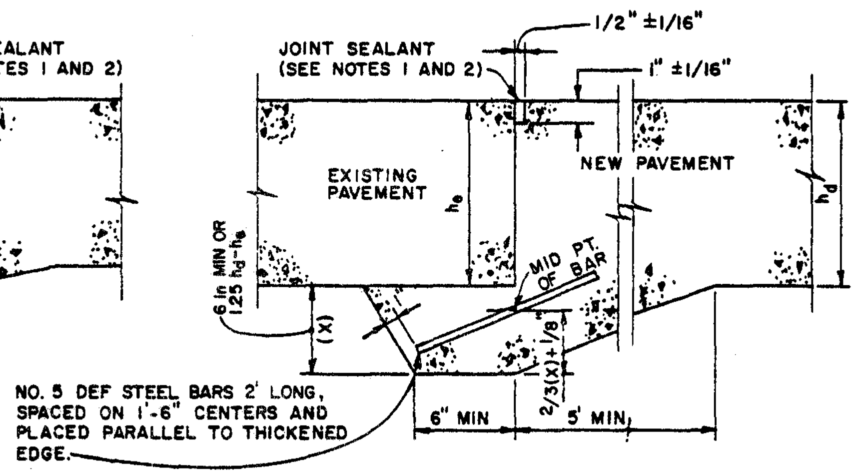


NOTE: Either one piece or threaded split type dowel may be used.

KEYED THICKENED EDGE LONGITUDINAL



SPECIAL JOINT BETWEEN NEW & EXISTING PAVEMENT
TRANSVERSE OR LONGITUDINAL (SEE PARA 2-4c)



NOTE: 1. Top of joint sealant will be 1/4 inch plus of minus 1/16 inch below top of pavement.

2. Joint sealant may be pourable or preformed type (see para 2-3e).

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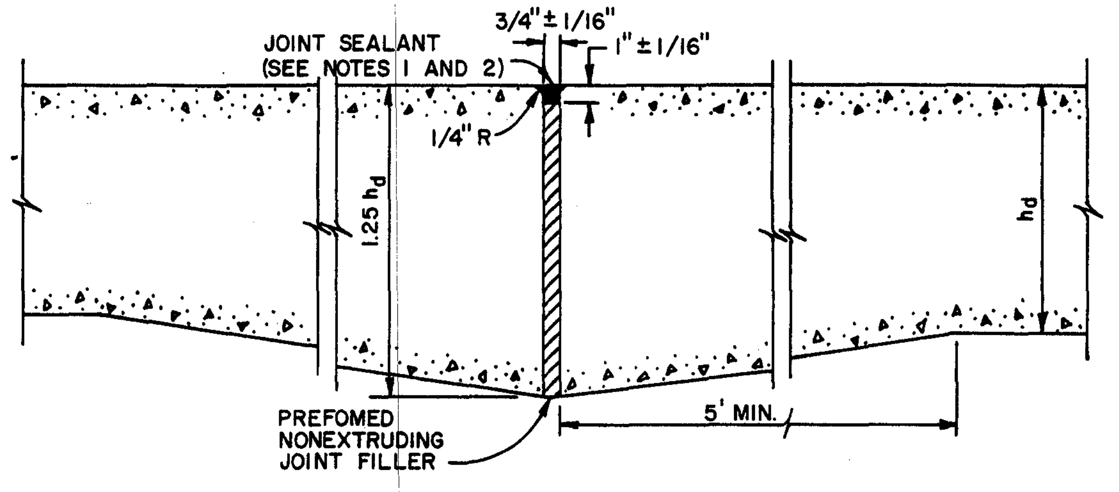
FIGURE 2-10. CONSTRUCTION JOINTS FOR JC PAVEMENTS

LONGITUDINAL



NOTES: 1. Top of joint sealant will be 1/4 inch plus or minus 1/16 inch below top of pavement.

2. Joint sealant may be pourable or preformed type (See para 2-3e).

3. Either one piece or threaded split type dowels may be used.

TRANSVERSE

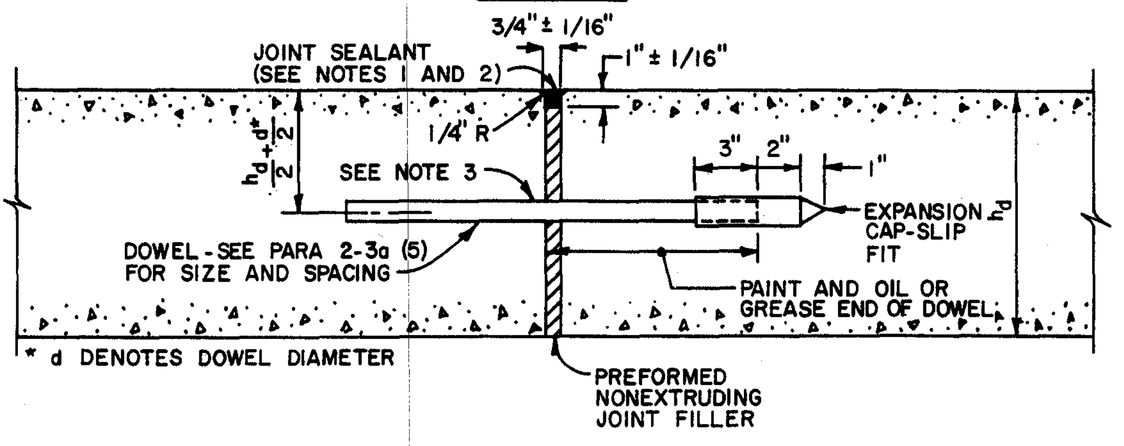


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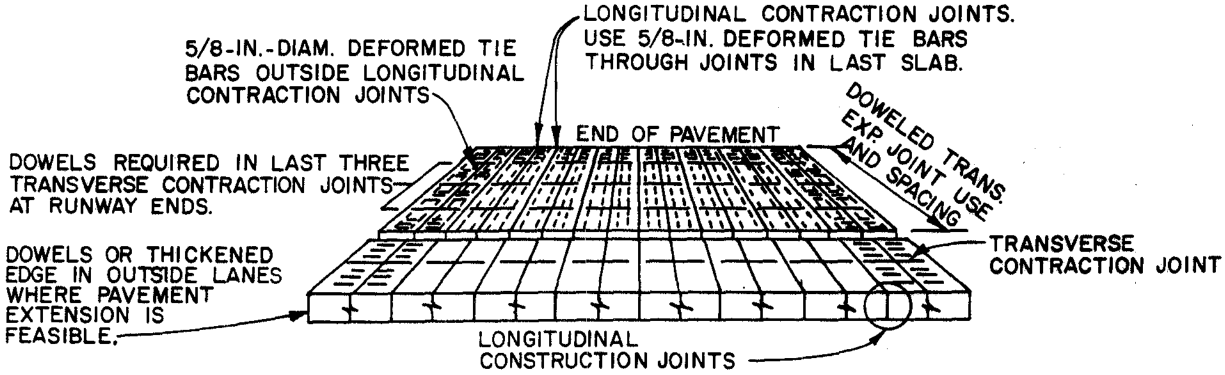
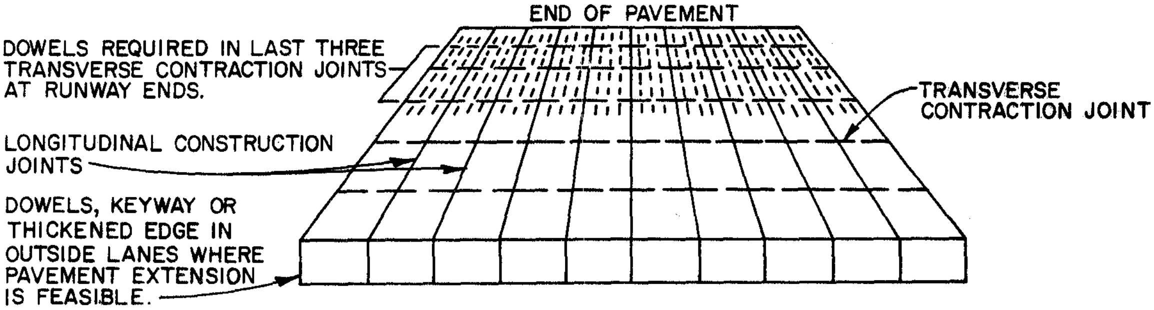
FIGURE 2-11. EXPANSION JOINTS FOR JC PAVEMENTS

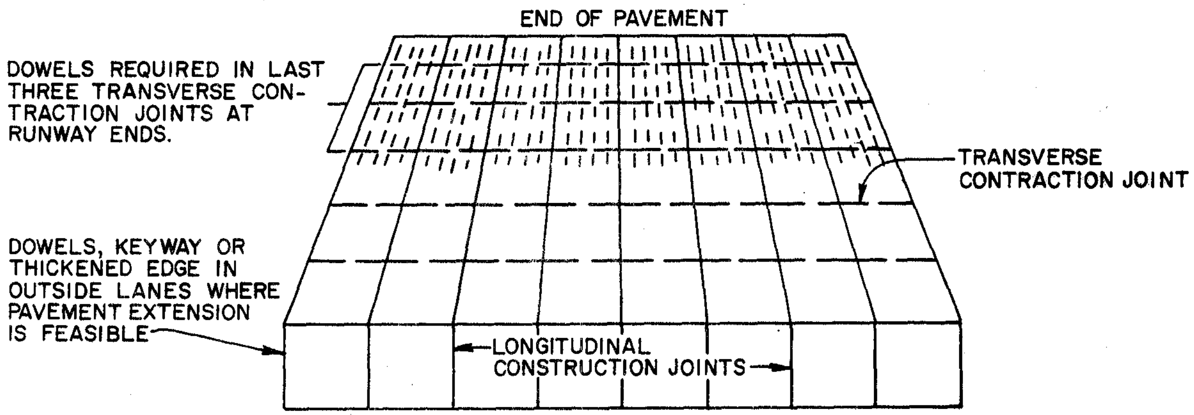


PAVEMENT THICKNESS LESS THAN 9 INCHES



Note: If lanes greater than 20 feet wide are used, longitudinal contraction joints must be placed in the center of each lane. Tie bars will be used in outside longitudinal contraction joints.

PAVEMENT THICKNESS, 9 TO 12 INCHES



Note: If paving lanes greater than 25 feet are used, longitudinal contraction joints must be placed in center of each lane.

PAVEMENT THICKNESS GREATER THAN 12 INCHES

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FIGURE 2-12. TYPICAL JOINTING

control of transverse cracking in most instances and may be used as a guide, subject to modification based on available information regarding the performance of existing pavements in the vicinity or unusual properties of the concrete. For best pavement performance, the number of joints should be kept to a minimum by using the greatest joint spacing that will satisfactorily control cracking. Experience has shown, however, that oblong slabs, especially in thin pavements, tend to crack into smaller slabs of nearly equal dimensions under traffic. Therefore, it is desirable, insofar as practicable, to keep the length and width dimensions as nearly equal as possible. In no case should the length dimension (in the direction of paving) exceed the width dimension more than 25 percent. Under certain climatic conditions, joint spacings different from those in table 2-1 may be satisfactory.

Table 2-1. Recommended Spacing of Transverse Contraction Joints

Pavement Thickness, inches	Spacing, feet
Less than 9	12-1/2 to 15
9 to 12	15 to 20
Over 12	20 to 25

(4) Spacing of longitudinal contraction joints. Contraction joints will be placed along the center line of paving lanes that have a width greater than the indicated maximum spacing of transverse contraction joints in table 2-1. Contraction joints may also be required in the longitudinal direction for overlays, regardless of overlay thickness, to match joints existing in the base pavement unless a bond-breaking medium is used between the overlay and base pavement or the overlay pavement is reinforced (para 3-3b(2)).

(5) Doweled and tied contraction joints. Dowels will be required in the last three transverse contraction joints back from the ends of all runways to provide positive load transfer in case of excessive joint opening due to progressive growth of the pavement. Similar dowel requirements may be included in the transverse contraction joints at the ends of other long paved areas, such as taxiways or aprons where local experience indicates that excessive joint opening may occur. In rigid overlays in Type A traffic areas, longitudinal contraction joints that would coincide with an expansion joint in the base pavement will be doweled. Dowel size and spacing will be as specified in table 2-2. Deformed tie bars, 5/8-inch diameter by 30 inches long, spaced on 30-inch centers, will be required in longitudinal contraction joints that fall 15 feet or less from the free edge of paved areas greater than 100 feet in width to prevent cumulative opening of these joints.

b. Construction joints. Construction joints may be required in both the longitudinal and transverse directions. Longitudinal

Table 2-2. Dowel Size and Spacing for Construction, Contraction, and Expansion Joints

Pavement Thickness, inches	Minimum Dowel Length, inches	Maximum Dowel Spacing, inches	Dowel Diameter and Type
Less than 8	16	12	3/4-inch bar
8 to and including 11.5	16	12	1-inch bar
12 to and including 15.5	20	15	1- to 1-1/4-inch bar, or 1-inch extra-strength pipe
16 to and including 20.5	20	18	1- to 1-1/2-inch bar, or 1- to 1-1/2-inch extra-strength pipe
21 to and including 25.5	24	18	2-inch bar, or 2-inch extra-strength pipe
Over 26	30	18	3-inch bar, or 3-inch extra strength pipe

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construction joints, generally spaced 20 to 25 feet apart but may reach 50 feet apart depending on construction equipment capability, will be required to separate successively placed paving lanes. Transverse construction joints will be installed when it is necessary to stop concrete placement within a paving lane for a sufficient time for the concrete to start to set. All transverse construction joints will be located in place of other regularly spaced transverse joints (contraction or expansion types). There are several types of construction joints available for use as shown in figure 2-10. These joints are described in paragraphs (1), (2), and (3) below. The selection of the type of construction joint will depend on such factors as the concrete placement procedure (formed or slipformed), pavement design classes, and foundation conditions.

(1) Doweled butt joint. The doweled butt joint is considered to be the best joint insofar as providing load transfer and maintaining slab alinement is concerned. Therefore, it is the desirable joint for the most adverse conditions, such as heavy loading, high traffic intensity, and lower strength foundations. However, because the alinement and placement of the dowel bars are critical to satisfactory performance, this type of joint is difficult to construct, especially for slipformed concrete. The doweled butt joint is required for all transverse construction joints.

(2) Thickened-edge joint. Thickened-edge-type joints may be used in lieu of other types of joints employing load transfer devices. The thickened-edge joint is constructed by increasing the thickness of the concrete at the edge to 125 percent of the thickness determined from paragraph 2-2. The thickness is then reduced by tapering from the free-edge thickness to the design thickness at a distance 5 feet from the longitudinal edge. The thickened-edge butt joint is considered adequate for the load-induced concrete stresses. However, the inclusion of a key in the thickened-edge joint provides some degree of load transfer in the joint and helps maintain slab alinement; although not required, it is recommended for pavement constructed on low- or medium-strength foundations. The thickened-edge joint may be used at free edges of paved areas to accommodate future expansion of the facility or where aircraft wheel loadings may track the edge of the pavement.

(3) Keyed joint. The keyed joint is the most economical method, from a construction standpoint, of providing load transfer in the joint. It has been demonstrated that the key or keyway can be satisfactorily constructed using either formed or slipformed methods. Experience has demonstrated that the required dimensions of the joint can best be maintained by forming or slipforming the keyway rather than the key. The dimensions and location of the joint (fig 2-10) are critical to its performance. Deviations exceeding the stated tolerances can result in failure in the joint. Experience has shown that the keyed joint may not perform adequately for high-volume medium

and heavy loads in pavements constructed on low- and medium-strength foundations. Tie bars in the keyed joint will limit opening of the joint and provide some shear transfer that will improve the performance of the keyed joints. However, tied joints in pavement widths of more than 75 feet can result in excessive stresses and cracking in the concrete during contraction.

c. Expansion joints. Expansion joints will be used at all intersections of pavements with structures and may be required within the pavement features. A special feature requiring expansion joints is a nonperpendicular pavement intersection. The two types of expansion joints are the thickened-edge and the doweled type (fig 2-11), both of which will be provided with a nonextruding-type filler material. The type and thickness of filler material and the manner of its installation will depend upon the particular case. Usually a preformed material of 3/4-inch thickness will be adequate; however, in some instances a greater thickness of filler material may be required. Where large expansions may have a detrimental effect on adjoining structures, such as at the juncture of rigid and flexible pavements, expansion joints in successive transverse joints back from the juncture should be considered. The depth, length, and position of each expansion joint will be sufficient to form a complete and uniform separation between the pavements or between the pavement and the structure concerned.

(1) Between pavement and structures. Expansion joints will be installed to surround, or to separate from the pavement, any structures that project through, into, or against the pavements, such as at the approaches to buildings or around drainage inlets and hydrant refueling outlets. The thickened-edge-type expansion joint will normally be best suited for these places.

(2) Within pavements. Expansion joints within pavements are difficult to construct and maintain, and they often contribute to pavement failures. Their use will be kept to the absolute minimum necessary to prevent excessive stresses in the pavement from expansion of the concrete or to avoid distortion of a pavement feature through the expansion of an adjoining pavement. The determination of the need for and spacing of expansion joints will be based upon: pavement thickness, thermal properties of the concrete, prevailing temperatures in the area, temperatures during the construction period, and the experience with concrete pavements in the area. Unless needed to protect abutting structures, expansion joints will be omitted in all pavements 10 inches or more in thickness and also in pavements less than 10 inches in thickness when the concrete is placed during warm weather, since the initial volume of the concrete on hardening will be at or near the maximum. However, for concrete placed during cold weather, expansion joints may be used in pavements less than 10 inches thick.

(a) Longitudinal expansion joints within pavements will be of the thickened-edge type (fig 2-11). Dowels are not recommended in longitudinal expansion joints because differential expansion and contraction parallel with the joints may develop undesirable localized strains and possibly failure of the concrete, especially near the corners of slabs at transverse joints.

(b) Transverse expansion joints within pavements will be the doweled type (fig 2-11). There may be instances when it will be desirable to allow some slippage in the transverse joints, such as at the angular intersection of pavements to prevent the expansion of one pavement from distorting the other. In these instances, the design of the transverse expansion joints will be similar to the thickened-edge slip joints (para 2-4b). When a thickened-edge joint (slip joint) is used at a free edge not perpendicular to a paving lane, a transverse expansion joint will be provided 75 to 100 feet back from the free edge.

(c) Dowels. The important functions of dowels or any other load-transfer device in concrete pavements are: to help maintain the alinement of adjoining slabs and to limit or reduce stresses resulting from loads on the pavement. Different sizes of dowels will be specified for different thicknesses of pavements (table 2-2). When extra-strength pipe is used for dowels, the pipe will be filled with either a stiff mixture of sand-asphalt or portland cement mortar, or the ends of the pipe will be plugged. If the ends of the pipe are plugged, the plug must fit inside the pipe and be cut off flush with the end of the pipe so that there will be no protruding material to bond with the concrete and prevent free movement of the dowel. Figures 2-9 through 2-11 show the dowel placement. All dowels will be straight, smooth, and free from burrs at the ends. One end of the dowel will be painted and oiled or greased to prevent bonding with the concrete. Dowels used at expansion joints will be capped at one end, in addition to painting and oiling or greasing, to permit further penetration of the dowels into the concrete when the joints close.

d. Special provisions for slipform paving. Provisions must be made for slipform pavers when there is a change in longitudinal joint configuration. The thickness may be varied without stopping the paving train, but the joint configuration cannot be varied without modifying the side forms, which will normally require stopping the paver and installing a header. The following requirements shall apply:

(1) The header may be set on either side of the transition slab with the transverse construction joint doweled as required. The dowel size and location in the transverse construction joint should be commensurate with the thickness of the pavement at the header.

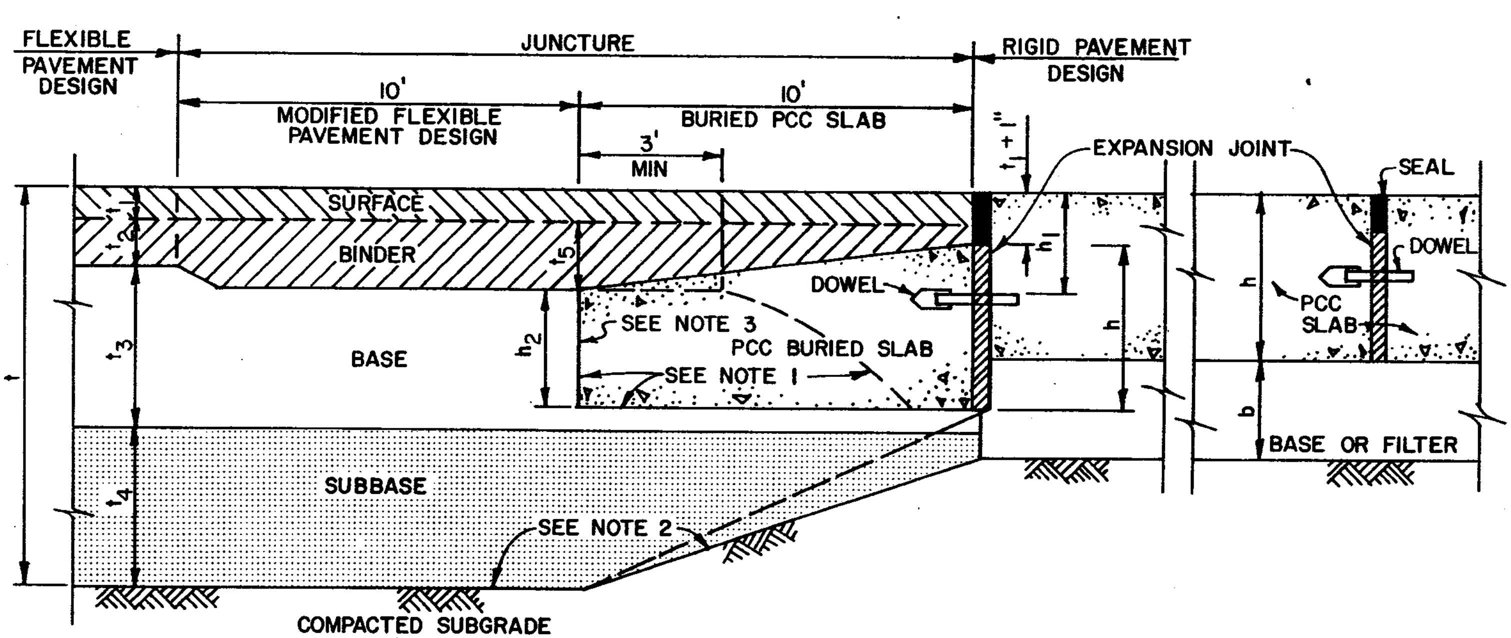
(2) When there is a transition between a doweled longitudinal construction joint and a keyed longitudinal construction joint, the longitudinal construction joint in the transition slab may be either keyed or doweled. The size and location of the dowels or keys in the transition slabs should be the same as those in the pavement with the doweled or keyed joint, respectively.

(3) When there is a transition between two keyed joints with different dimensions, the size and location of the key in the transition slab should be based on the thickness of the thinner pavement.

e. Joint sealing. All joints will be sealed with a suitable sealant to prevent infiltration of surface water and solid substances. JFR sealants will be used in the joints or aprons, warm-up holding pads, hardstands, washracks, and other paved areas where fuel may be spilled during the operation, parking, maintenance, and servicing of aircraft. In addition, heat-resistant JFR joint sealant materials will be used for runway ends and other areas where the sealant material may be subject to prolonged heat and blast of jet aircraft engines. Non-JFR sealants will be used in joints of all other airfield pavements. An optimal sealant, meeting both the heat- and blast-resistant JFR and non-JFR sealant requirements, is a preformed polychloroprene elastomeric material. Preformed sealants must have an uncompressed width of not less than twice the width of the joint sealant reservoir. The selection of a pourable or preformed sealant should be based upon the economics involved. Compression-type preformed sealants are recommended when the joint spacings exceed 25 feet and are required when joint spacings exceed 50 feet.

2-4. Special joints and junctures. Situations will develop where special joints or variations of the more standard type joints will be needed to accommodate the movements that will occur and to provide a satisfactory operational surface. Some of these special joints or junctures are as follows:

a. Juncture between rigid and flexible pavements. Experience has shown that objectionable roughness often develops at the juncture of a rigid and flexible pavement under aircraft traffic. This roughness generally takes the form of subsidence or shoving. In order to minimize the roughness, a juncture design has been prepared as illustrated in figure 2-13. The junctures are intended for critical traffic areas or in areas where slight deviations from the design grade are objectionable. Specifically, the junctures should be incorporated where rigid pavement joins flexible pavement at all transverse junctures in runway and taxiways. These special junctures will not be required between aprons or in junctures to blast pads, overruns, and stabilized shoulders. The buried rigid-slab-type juncture as detailed in figure 2-13 is provided for all pavement designs. No joints will be required in the buried rigid slab. Provide the second expansion joint



NOTES:

1. Compact flexible pavement to dotted line. Cut out to solid line not disturbing the materials outside limits of buried slab.

2. Excavate and compact subgrade to dotted line if a base or filter is not used beneath PCC. Excavate and compact subgrade to solid line when base or filter course is used beneath PCC.

3. Place PCC buried slab directly against cut back base course. No form will be used.

4. Top lift of binder to be placed and rolled transversely. Surface coarse placed and rolled longitudinally stopping rollers on rigid pavement.

LEGEND TO THICKNESS

SYMBOL	HEAVY AND MEDIUM LOAD DESIGN	LIGHT AND SHORTFIELD LOAD DESIGN
h	Design thickness of PCC	Design thickness of PCC
h_1	$\frac{h + t_1 + 1}{2}$	$\frac{h + t_1 + 1}{2}$
h_2	$h - t_5 + 1''$ but not less than 6"	$h - t_5 + 1$ but not less than 4"
b	Thickness of base or filter	Thickness of base or filter
t	Design thickness of flexible pavement	Design thickness of flexible pavement
t_1	Design thickness of surface course	Design thickness of surface course
t_2	Design thickness of binder course	Design thickness binder course
t_3	Design thickness of base course	Design thickness of base course
t_4	Design thickness of subbase course	Design thickness of subbase course
t_5	$h - h_2 + 1$ but not less than t_2	$h - h_2 + 1$ but not less than t_2

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FIGURE 2-13. DESIGN OF RIGID-FLEXIBLE PAVEMENT JUNCTURE between the rigid pavements when the rigid pavement is 1,600 feet in length or longer; install the second expansion joint in the last joint of the rigid pavement. When joining a new rigid pavement to an existing flexible pavement, cut the existing flexible pavement back to the dimension for "buried PCC slab" only. The portion labeled "modified flexible pavement design" will not be incorporated because of the possibility of destroying the existing density of the base course materials. When the juncture is installed during the construction of a new flexible pavement joining an existing rigid pavement, the existing rigid pavement will be drilled and doweled for the expansion joint. The dowels will be bonded in the existing rigid pavement with epoxy grout.

b. Slip-type joints. At the juncture of two pavement facilities, such as a taxiway and runway, expansion and contraction of the concrete may result in movements that occur in different directions. Such movements may create detrimental stresses within the concrete unless a provision is made to allow the movements to occur. At such junctures, a thickened-edge slip joint should be used to permit the horizontal slippage to occur. The design of the thickened-edge slip joint will be similar to the thickened-edge construction joint (fig 2-10). The bond-breaking medium will be either a heavy coating of bituminous material not less than 1/16 inch in thickness when joints match or a normal nonextruding-type expansion joint material not less than 1/4 inch in thickness when joints do not match. The 1/16-inch bituminous coating may be either a low penetration (60-70 grade asphalt) or a clay-type asphalt-base emulsion similar to that used for roof coating and will be applied to the face of the joint by hand brushing or spraying.

c. Special joint between new and existing pavements. A special thickened-edge joint design (fig 2-10) will be used at the juncture of new and existing pavements for the following conditions:

- When load-transfer devices (keyways or dowels) or a thickened edge was not provided at the free edge of the existing pavement.

- When load-transfer devices or a thickened edge was provided at the free edge of the existing pavement but neither met the design requirements for the new pavement.

- For transverse contraction joints, when removing and replacing slabs in an existing pavement.

- For longitudinal construction joints, when removing and replacing slabs in an existing pavement if the existing load-transfer devices are damaged during the pavement removal.

- Any other location where it is necessary to provide load transfer for the existing pavements.

The special joint design may not be required if a new pavement joins an existing pavement that is grossly inadequate to carry the design load of the new pavement or if the existing pavement is in poor structural condition. If the existing pavement can carry a load that is 75 percent or less of the new pavement design load, special efforts to provide edge support for the existing pavement may be omitted; however, if omitted, accelerated failures in the existing pavement may be experienced. Any load-transfer devices in the existing pavement should be used at the juncture to provide as much support as possible to the existing pavement. The new pavement will simply be designed with a thickened edge at the juncture. Drilling and grouting dowels in the existing pavement for edge support may be considered as an alternative to the special joint; however, a thickened-edge design will be used for the new pavement at the juncture.